SNPE MATÉRIAUX ÉNERGÉTIQUES
GROUPE SNPE

CLEXTRAL

Continuous Twin Screw Processes:

Evolution of the design of the extruders in regards to safety concerns

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Summary Slide

- Twin Screw Extrusion & Energetic Material
- Safety Organs
- Some Twin Screw Extruders for Energetic Material Processing
- Other Safety Aspects
- Industrial Results of Continuous Process
- Conclusion

Twin Screw Extrusion & Energetic Material

- Continuous Process:
  - Gravimetric feeding
  - Mixing, plastification, extrusion
  - Continuous: no difference between batches
- Repeatability:
  - Level of control of all the extrusion parameters
  - Specific screw profile
  - Data recording
- Homogeneity
  - Quality of the mixing (macro and micro-mixing)
  - Thin Layer

Twin Screw Extrusion & Energetic Material

- Flexibility
  - Possibility to process various products
- Safety
  - Low quantity of product at any time in the extruder (about 3 kg)

Twin Screw Extrusion & Energetic Material

- Constraints:
  - Sensitivity to static electricity
  - Sensitivity to shear
  - Sensitivity to shocks
  - Sensitivity to warm-up
  - Cook-off phenomenon
  - Temperature of process: burning
  - Shock, explosion

Twin Screw Extrusion & Energetic Material

- During the extrusion process, the energetic material explores all the internal volume of the extruder (screw / barrel assembly), therefore:
  - Performances are sensitive to internal defects and to the mixing, kneading and forming process (rheology)

- Rheology
  - In high shearing areas, recirculation of the paste within the screws and the barrel gap => increase of temperature
  - Necessity to adjust the gap between the screws and the barrel (minimize it) without creating to much metal/metal contact.
  - Specific profile for each product, sometimes, specific screw design as well

Twin Screw Extrusion & Energetic Material

- Specific safety organs:
  - Volume able to detonate
  - Points to monitor:
    - Feeding
    - Kneading / mixing
    - Extrusion (die level)
  - Safety organs
    - Pressure release at the die level
    - Pressure release along the barrel

Twin Screw Extrusion & Energetic Material

- Mechanical Construction (quality and precision):
  - Gap screw/barrel
  - Mastering the addition of manufacturing tolerances along the modular screw profile
- Importance of thermal exchange between screws and barrels
- Cooling of the shafts and of the barrels

- The product quality calls for a control of feeding weights of 3‰

Safety Organs

- Opening of the extruder
  - Crocodile
  - Clamshell through “Arc de Triomphe”: clamshell
  - Hydraulic opening with sliding barrel (patented system)
- Pressure release
  - Barrel, die, crush rings
- Instrumentation and automation (functional analysis)
- Others Important aspects:
  - Metallurgy
  - Design
  - Torque control
  - Drive: hydraulic or electric
  - Quality control: ISO 9001+

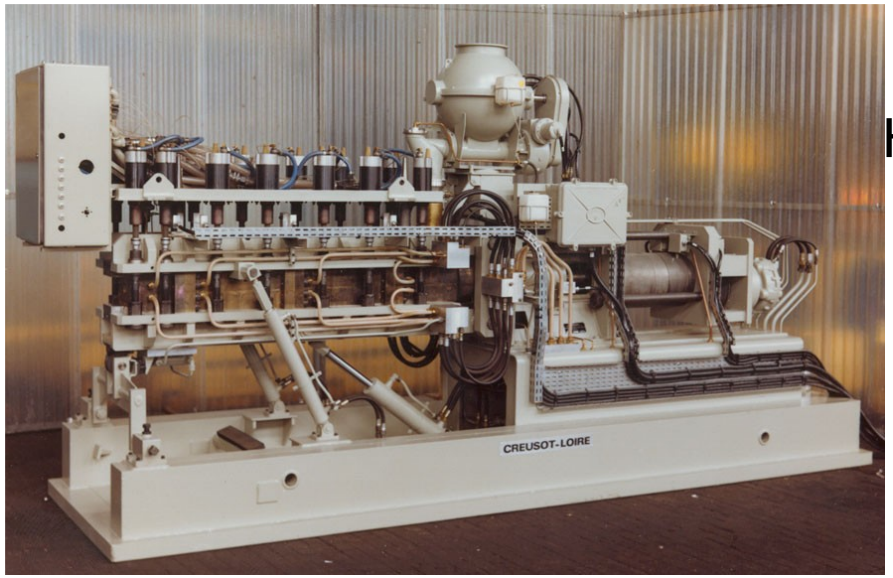
Some Twin Screw Extruders for Energetic Material Processing

• 1976	KRO 82	Propergol SD
• 1985	KRO 72	Propergol SD
• 1989	BC45	R&D
• 1995	BC72	Air bags gas generator
• 1999	BC21	R&D
• 2000	BC72	Air bags gas generator
• 2002	BC72	Air bags gas generator

1976 – KRO 82

Propergol SD production twin-screw extruder

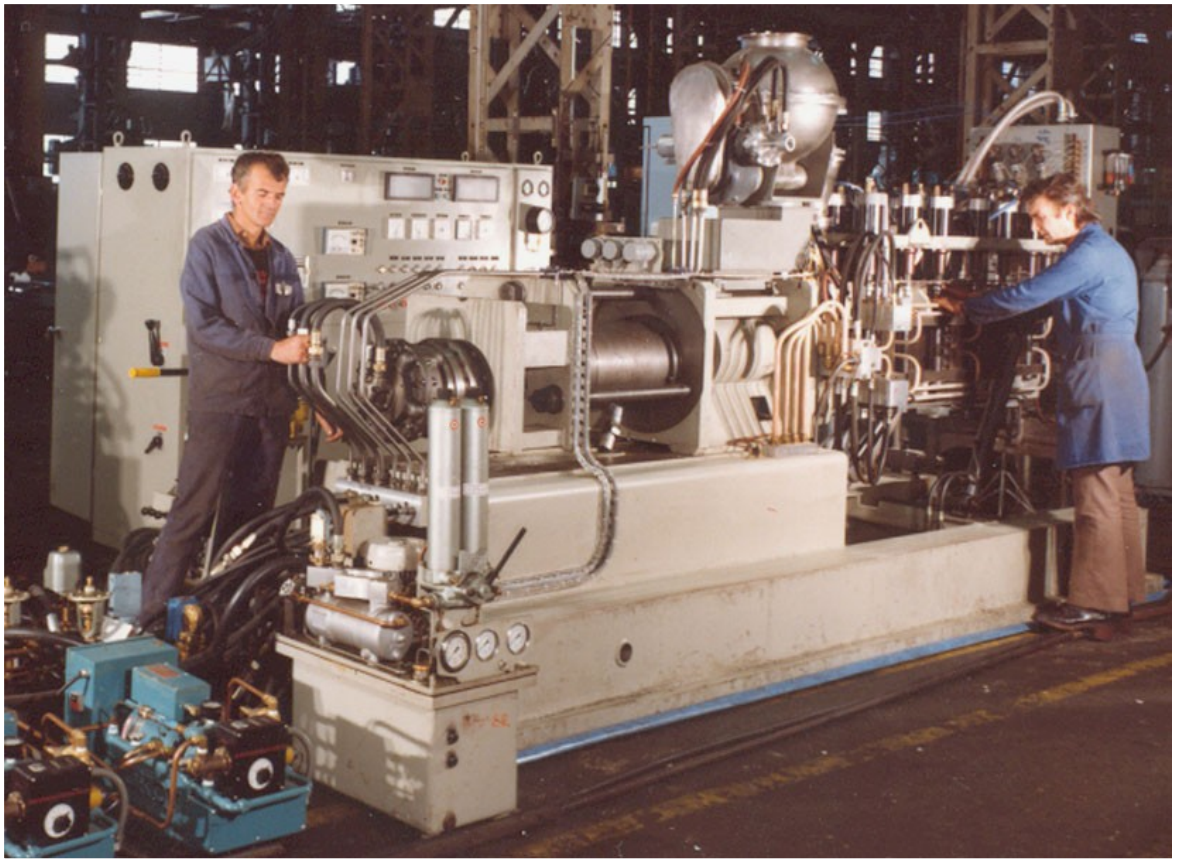
‘crocodile’ Opening



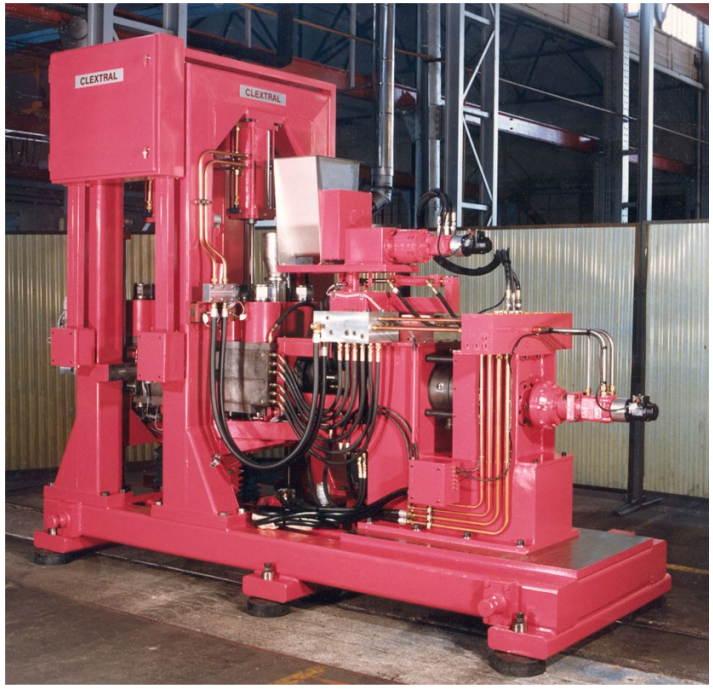
Hydraulic drive

Brass screws and nitrided barrels

1976 – KRO 82

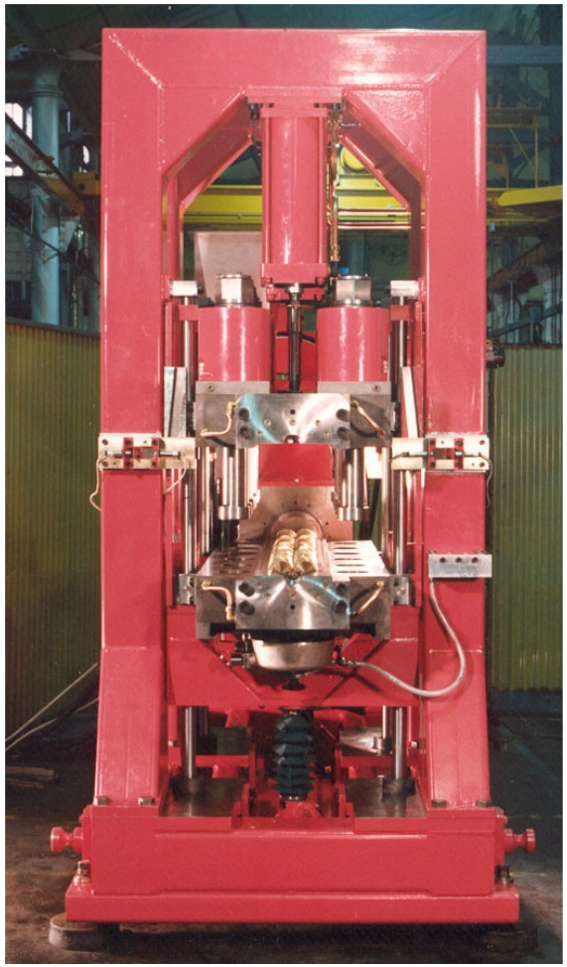


1985 – KRO 72

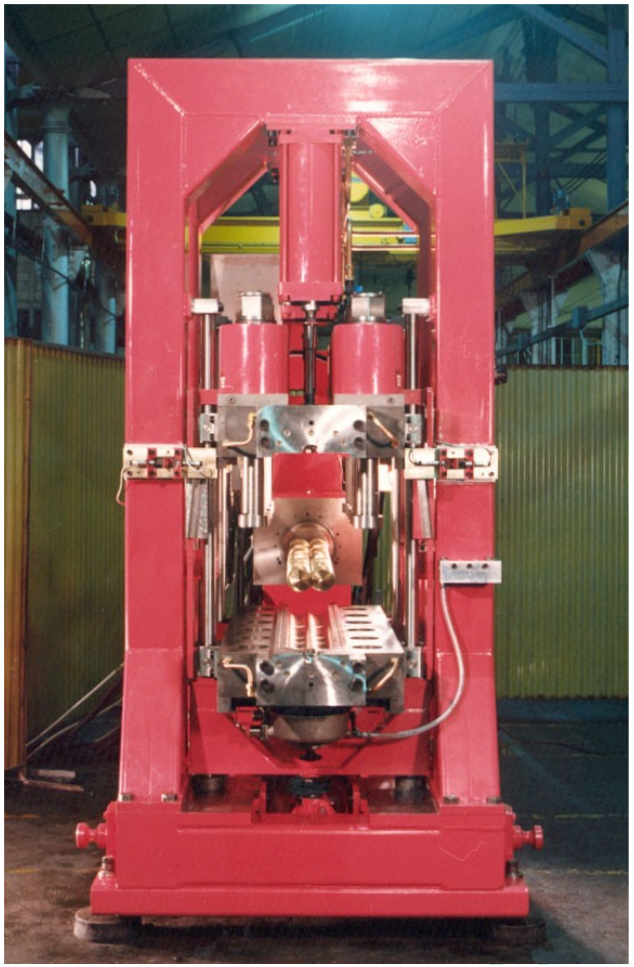


Hydraulic Drive
Clamshell opening with pneumatic and Hydraulic system.
Hydraulic for locking in place the barrels, pneumatic to full opening

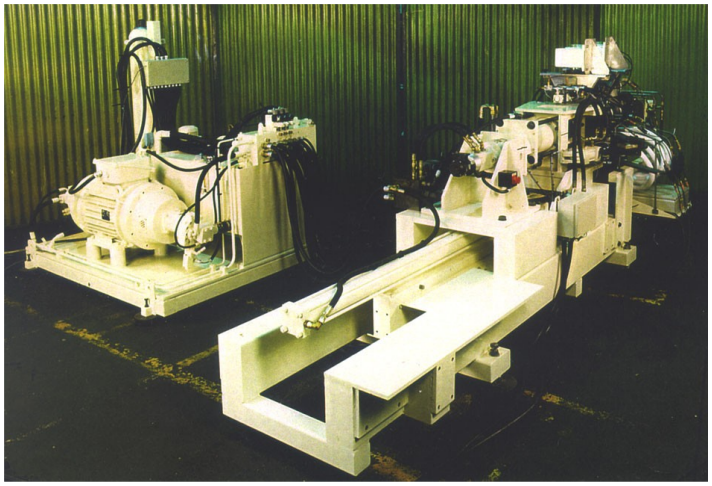
1985 – KRO72

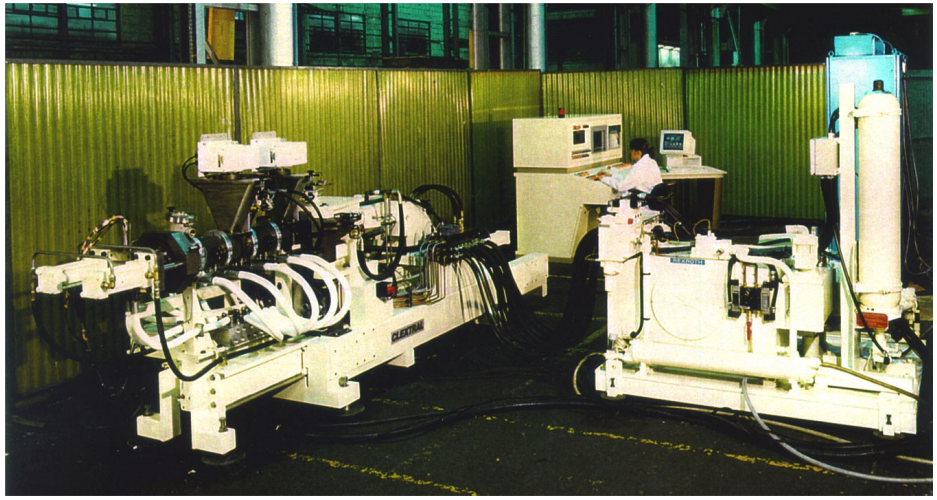


Two-step opening Hydraulic jacks to open and close the barrel



1989 – BC45





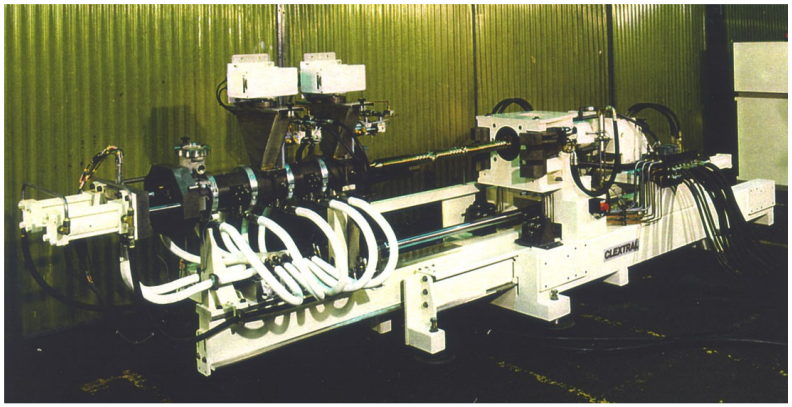
R&D extruder for energetic material

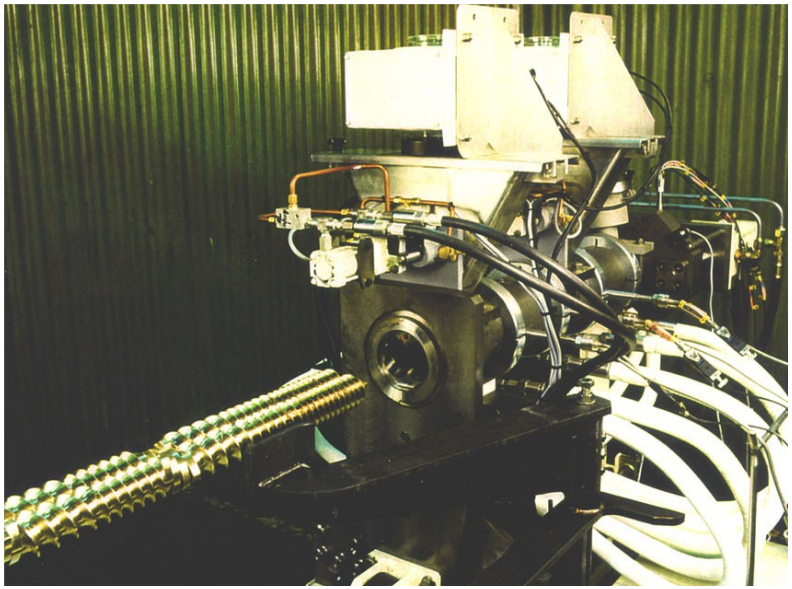
Smaller machine: 50mm

Hydraulic drive

PLC control

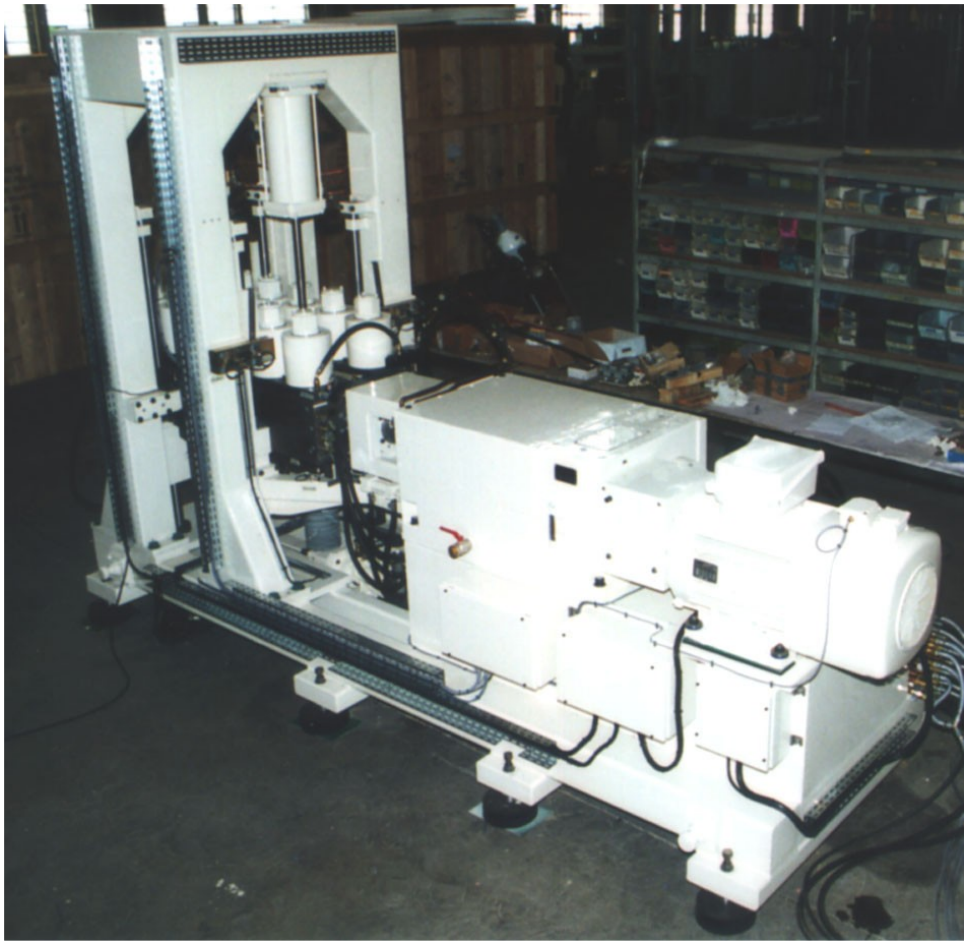
1989 – BC45





First twin screw extruder with Hydraulic opening of the barrel with the sliding system

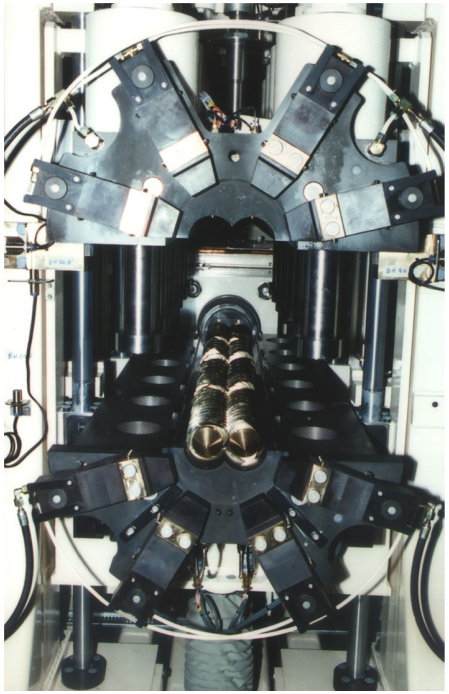
1995 – BC72

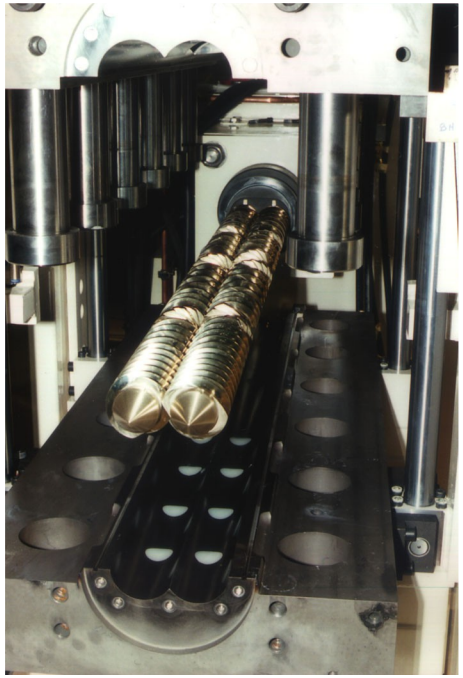


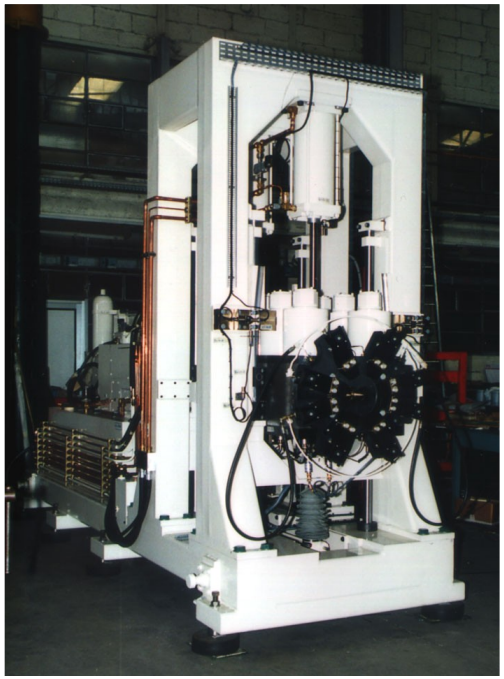
Introduction of electrical drive instead of hydraulic drive (advances in motors available)

New gearbox design allowing higher torque

1995 – BC72

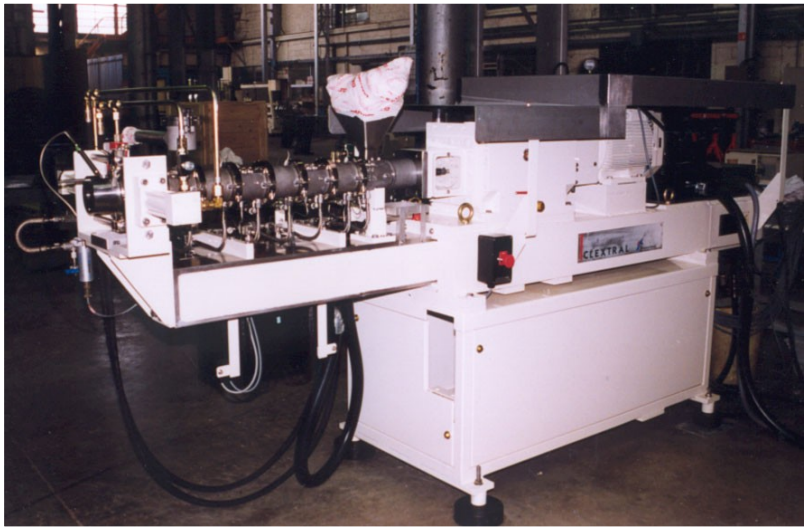


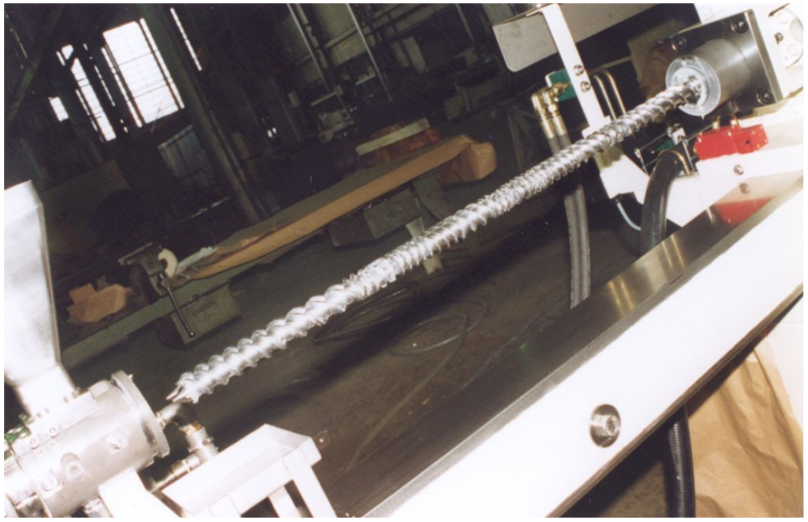




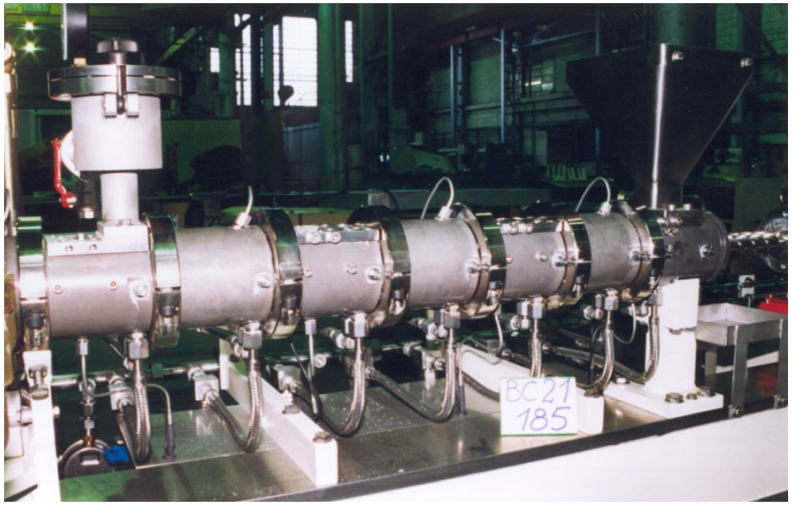
Clamshell opening includes special pressure release system at the die level
Brass screws and nitrided barrels

1999 – BC21





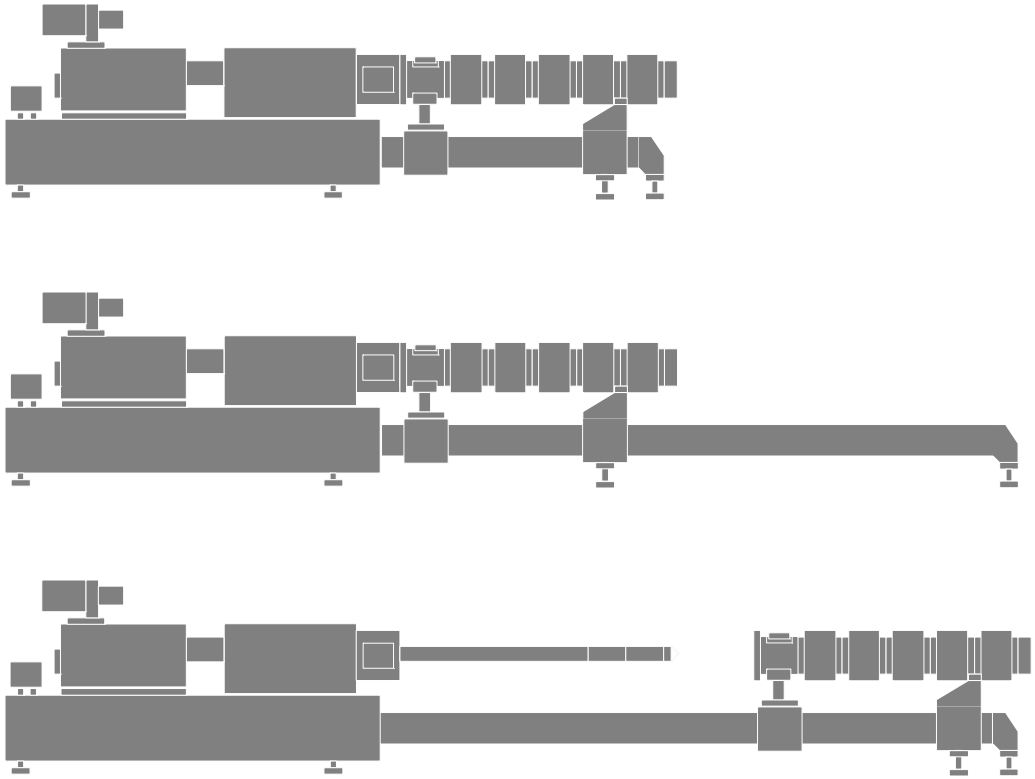
Small R&D TSE
25 mm diameter
Electrical drive
Simpler machine
Hydraulic Sliding
Opening of the barrel assembly



2000 – BC72

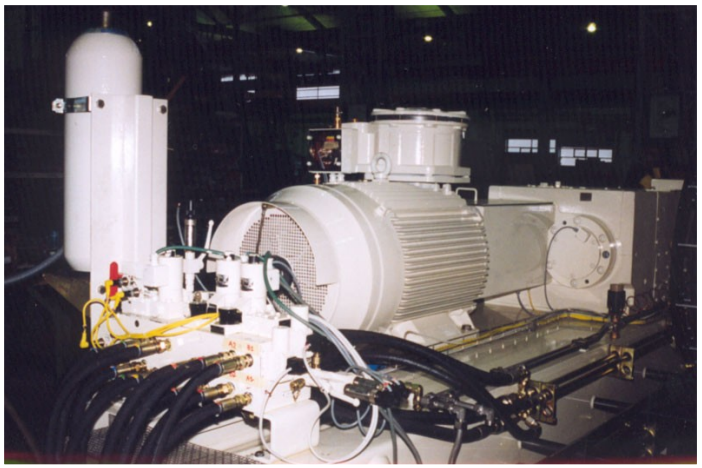
Two step opening of the barrel:
Possibility of fast pressure release with small opening of the barrel

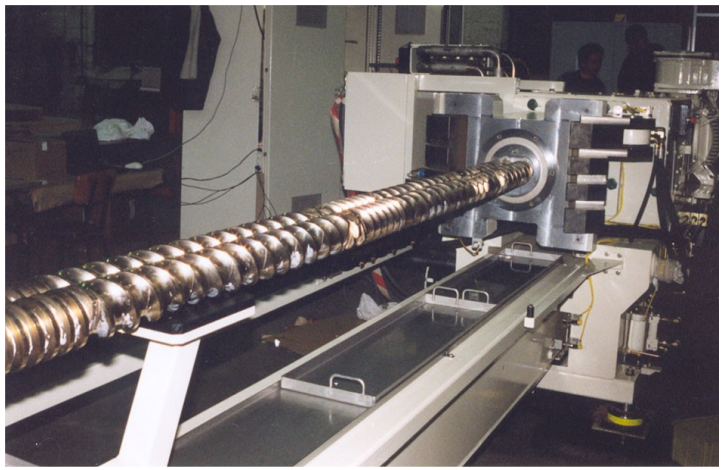
(patented system)

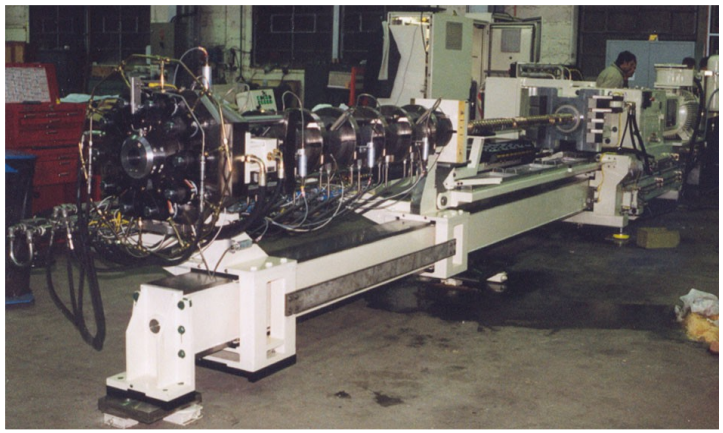


2000 – BC72

Air bag gas generator



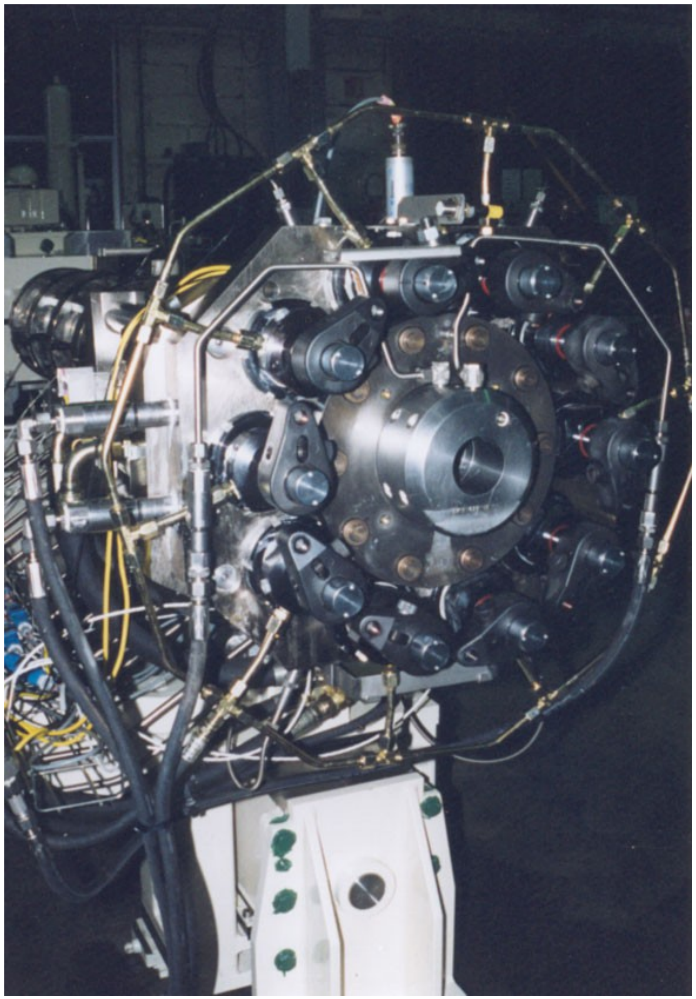




Electrical drive

First introduction of two-step sliding hydraulic opening for production twin-screw extruder

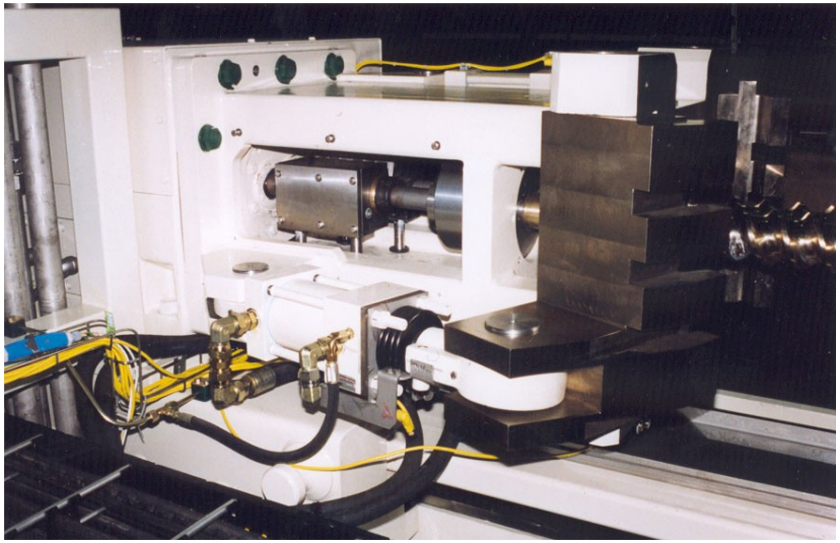
2000 – BC72



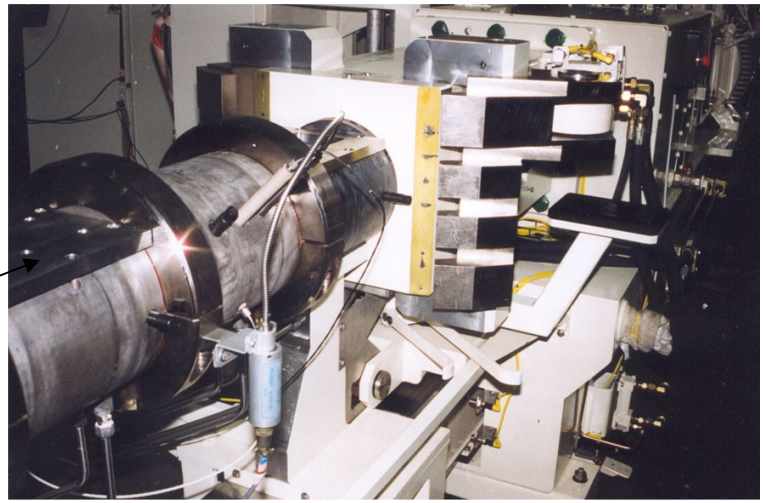
Optimization of the pressure release at the die level

Hydraulic system to clamp the die in place

2000 – BC72

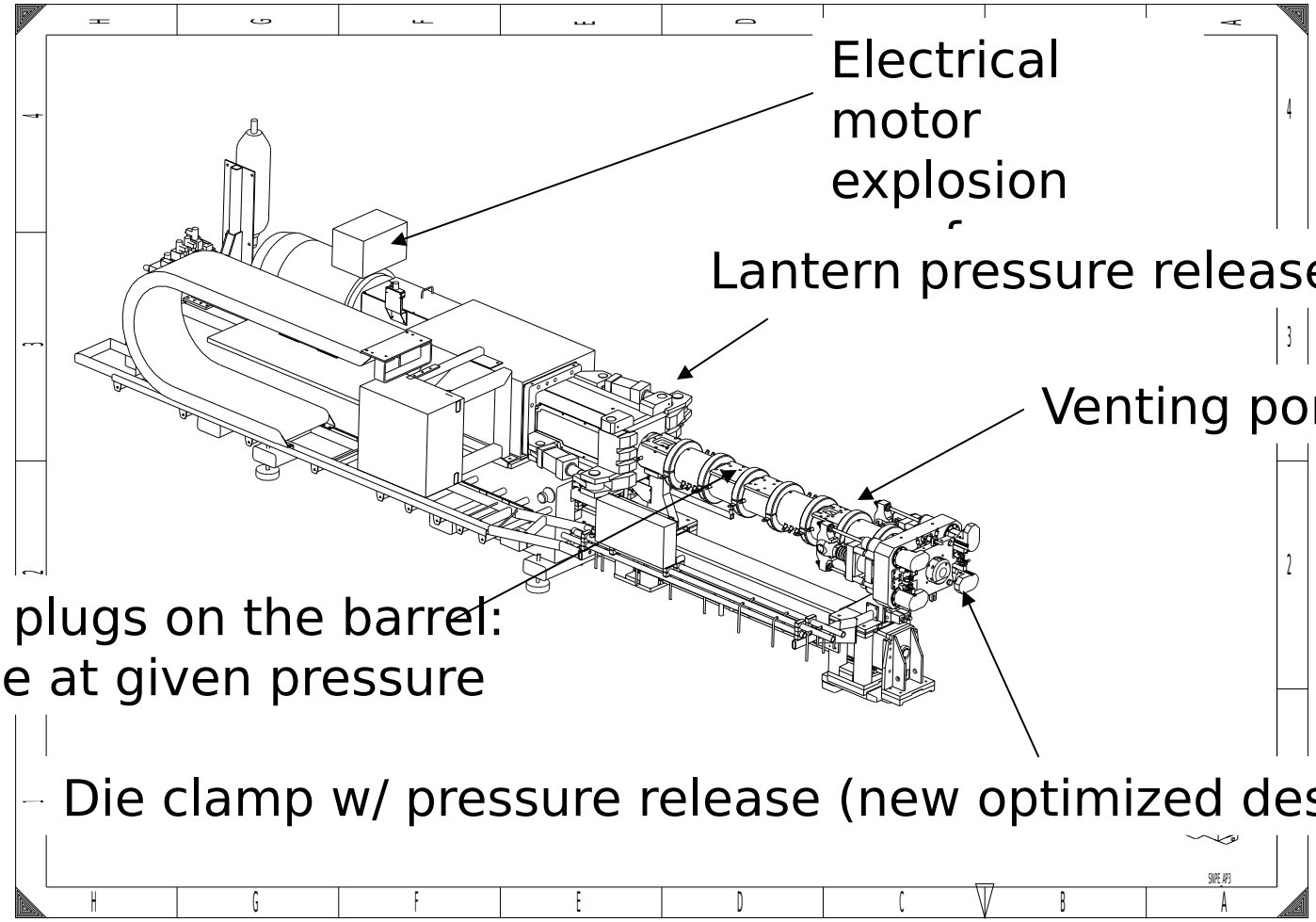


Pressure release at the lantern with hydraulic jaws



Special safety plugs

2002 – BC72


Electrical motor explosion
Lantern pressure release
Venting port
Safety plugs on the barrel:
Release at given pressure
Die clamp w/ pressure release (new optimized design)

Other Safety Aspects

- Pressure Release
  - Level 1, through instrumentation: temperature, pressure monitoring
  - Level 2, emergency level: crush rings, safety plugs
  - Pressure release in less than 1 second
- Automation and instrumentation
  - Importance of the functional analysis: PLC
  - Full instrumentation of the barrel (temperature, pressure) and the extruder (torque, gearbox pressure, etc.)
  - Monitoring of parameters and level of alarms
  - Management of opening sequences for normal and emergency opening
- Metallurgy
  - Avoid spark and too much metal to metal contact

Industrial Results of Continuous Process

- Industrial use of the system for full production since 1996

- Quality of Products
  - The quality of the final extruded product is the same as or better than from a batch system
  - 300 tons/year
  - Burning rate repeatability (standard deviation) for a composite propergol

    batch process $\sigma \approx 1\%$

    continuous process $\sigma \approx 0.7\%$

Industrial Results of Continuous Process

- Industrial tools
  - Demonstration that the continuous process is viable in an industrial environment and can be considered as a mature industrial production tool

- Safety Environment
  - Due to the small amount of product being processed and the safety devices on the extruder, any incident is limited => Impact on equipment and downtime reduced and consequences “manageable” for a production factory
  - No major incidents in 6 years operation despite newly trained operators

Conclusion

- Very demanding process calls for high quality equipment and innovative design: “Swiss Watch” precision
- Importance of safety features for the personnel and the equipment
- Evolution of the design with evolution of the various technologies available
- Evolution of norms along the way (safety norms for instance)
- 1 customer = 1 application = 1 machine (BC series, Evolum® high torque series) with specific design choices
- Proven technology platform = quality of production & safety records